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Sources of Emissions of Polychlorinated Biphenyls into the Ambient Atmosphere and Indoor Air

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SOURCES OF EMISSIONS OF POLYCHLORINATED BIPHENYLS
INTO THE AMBIENT ATMOSPHERE AND INDOOR AIR

by

Kathryn E. MacLeod
Analytical Chemistry Branch
Environmental Toxicology Division
Health Effects Research Laboratory
Research Triangle Park, N.C. 27711

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
HEALTH EFFECTS RESEARCH LABORATORY
RESEARCH TRIANGLE PARK, N.C. 27711

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FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The Health Effects Research Laboratory, Research Triangle Park, conducts a coordinated environmental health research program in toxicology, epidemiology, and clinical studies using human volunteer subjects. These studies address problems in air pollution, non-ionizing radiation, environmental carcinogenesis and the toxicology of pesticides as well as other chemical pollutants. The Laboratory participates in the development and revision of air quality criteria documents on pollutants for which national ambient air quality standards exist or are proposed, provides the data for registration of new pesticides or proposed suspension of those already in use, conducts research on hazardous and toxic materials, and is primarily responsible for providing the health basis for non-ionizing radiation standards. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of health care and surveillance of persons having suffered imminent and substantial endangerment of their health.

This report represents a research effort in the field of monitoring for airborne chemical pollutants. The emphasis of the project was to determine the sources of atmospheric emissions of polychlorinated biphenyls (PCB). Such data is required for the continued development of criteria for ambient air quality standards.

F. G. Hueter, Ph.D.
Director
Health Effects Research Laboratory (MD-51)

ABSTRACT

Polychlorinated biphenyls (PCB) have been identified in air samples from many parts of the world since the 1960s. This study was undertaken to identify and compare different sources of PCB in indoor and outdoor air. Almost all sampling was performed in central North Carolina. The suspected sources that were tested were fluorescent light ballasts, landfills, electrical substations, a transformer manufacturer, and the sites of illegal dumping.

Defective light ballasts emit large quantities of PCB and are an important indoor source. Capacitors in small electrical equipment may also be an important source. In general, indoor air levels of PCB were at least one order of magnitude higher than outdoor levels. The data indicate that the landfills and electrical substations tested are not major sources of PCB. The transformer manufacturer had elevated levels of PCB in the immediate area of the plant but did not contribute greatly to the levels found off the property. The spill sites also had elevated levels of the contaminant in their immediate area, but the levels 50-100 m away were normal for rural areas.

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SECTION I

CONCLUSIONS

Defective light ballasts manufactured prior to 1972 can release large quantities of polychlorinated biphenyls (PCB) into the air and appear to be an important source of indoor air pollution. Capacitors in small electrical equipment may also be an important source. In general, indoor air levels of PCB are at least one order of magnitude higher than outdoor levels. The data indicate that the landfills and electrical substations tested are not major sources of atmospheric emission of PCB. Manufacturing and spill sites were found to have elevated levels of the contaminant in the air immediately surrounding the areas, but the levels 500 m away were normal for rural areas.

SECTION II

INTRODUCTION

The polychlorinated biphenyls (PCB) are a family of chemicals that have been known to chemists since the 19th century and have found many industrial uses during this century.¹ They were first commercially available in this country in 1929 and were manufactured by the Monsanto Corporation between 1957 and mid-1977 in vast quantities as mixtures under the trade name Aroclor. (PCB imports only accounted for about 1% of the total used in the United States up to 1972 but have been rising.²) Monsanto marketed at least nine different Aroclors which were distinguished by the percent chlorination and had physical properties varying from clear mobile oil to yellow, sticky, viscous resin to white powder. These different mixtures found industrial uses in such diverse products as textile dyes, printing inks, fireproofing agents, pesticide extenders, hydraulic fluids, dielectrics in capacitors and transformer fluids. Their desirable qualities include chemical and thermal stability, non-flammability, electrical insulating properties, adherence to smooth surfaces and solubility in most common organic solvents. They are hydrophobic and resistant to acids, bases and oxidation.

By 1966, Monsanto was producing almost 30 million kg of these mixtures in a single year. This was the same year that the New Scientist contained a note about the discovery of PCB in the Swedish environment.³ In October, 1968, rice-bran oil manufactured in Kitakyushu City, Japan, was accidentally contaminated by large quantities of Kanechlor 400, a Japanese commercial mixture of PCB containing 48% chlorine. At least 1000 people of all ages

were poisoned by consuming this contaminated oil. Symptoms of the disease, which has come to be called "Yusho" included chloracne, eye discharges, hyperpigmentation of skin and nails, swelling of upper eyelids, and still-birth.⁴ Over the next few years, several investigators reported finding PCB in everything from Antarctic snow⁵ to mothers' milk⁶ to Icelandic plants and animals.⁷ The very properties that made PCB desirable for industrial uses assured that they would not break down quickly in the environment. PCB were on the way to becoming as universal a pollution problem as DDT.

After the Yusho incident and other PCB accidents in this country, the general population became more concerned about the environment and more aware of the adverse effects of pollution at this time. In 1971, with the mounting evidence against PCB, Monsanto voluntarily cut back production of the Aroclors, ceased manufacturing the most highly chlorinated mixtures and restricted sales to uses in closed systems only. At this time they also introduced a new PCB mixture, Aroclor 1016, which contained significantly less of the more highly chlorinated isomers than the Aroclor 1242 which it was designed to replace. In October, 1977, they ceased making all PCB. The problem of universal contamination is still present, however, with atmospheric PCB concentrations being reported in the ng/m^3 range from such diverse places as Rhode Island,⁸ Bermuda⁹ and Southern California.¹⁰

The existing U. S. Occupational Safety and Health Agency standard for a safe workplace environment is 1 mg/m^3 time-weighted-average permissible air concentration for an 8 to 10 hr. workday, 40 hr. work week. In light of recent evidence suggesting that PCB may be potential carcinogens, the National Institute for Occupational Safety and Health has recommended

a new criterion of $1 \mu\text{g}/\text{m}^3$ (based on the supposed analytical detection limit) for all carcinogens including PCB.⁴

Since PCB were used so enthusiastically in the 1960s and early 1970s, there is still a large reservoir of the material capable of entering the atmosphere from different sources. Every step in the process from the manufacturing of PCB themselves to the final disposal of the worn out product is a potential source of loss of PCB into the atmosphere. In their 1972 paper, Nisbet and Sarofim¹¹ estimated that between 1930 and 1970, 2.7×10^4 metric tons of PCB had been released into the air; 5.4×10^4 metric tons into lakes, rivers and other bodies of water and that an additional 2.7×10^5 metric tons were in dumps and landfills. They based their calculations on losses during the manufacture of PCB and PCB-containing products, leaks from the products during use, lifetime of the products and method of disposal of scrap, waste and used products.

Since PCB are no longer manufactured in the United States, several of the sources suggested by early investigators such as vaporization of PCB containing paints and plasticizers are less important. Today's most likely sources are considered by many to be: incinerators, dumps and landfills, leaking transformers and capacitors, manufacturing sites and deliberate spills. While many people are aware of the presence of PCB in the air, up to this time very little actual sampling has been undertaken to confirm the sources. After cataloging the various suspected sources of PCB emission into the atmosphere, this study was undertaken to survey a number of these sources and to determine the aerial PCB concentrations in their vicinity.

Survey Sites

Dumps and landfills have been estimated to contain 2.7×10^5 metric tons of PCB and, therefore, are a very likely source of atmospheric contamination. One landfill that is presently in operation and three that were in use prior to 1971, but are now closed, were chosen as sites for sampling in this study. The landfill presently in use is the Durham, North Carolina, city landfill. The three closed landfills are the old Durham, Raleigh and Goldsboro, North Carolina, municipal landfills. Of these four, only the one at Goldsboro has had known dumping of PCB.

Transformers accounted for 19% of the domestic use for Aroclors between 1960 and 1971 and with capacitors, the only use since 1972. There are literally thousands of electrical substations all across the United States with large transformers containing an average of 689 liters (1131 kg) of askarel, the PCB containing fluid. These transformers are near buildings and transportation facilities and are sitting out exposed to the elements during their 25-30 year lifetimes.¹² These seemed to be excellent potential sources of contamination, so five of these substations were surveyed during this study.

Another potential source of PCB is the manufacturing sites across the country where PCB are being used or have previously been used. Prior to 1971, little care was taken in the handling, storage, cleanup or disposal of PCB at these sites. One of the thirteen transformer manufacturers in the country has a plant in Goldsboro, North Carolina. The company allowed the area around the plant to be tested for PCB emissions.

Perhaps the most dangerous source of emissions is the site of deliberate illegal dumping of PCB or PCB-containing wastes. The highways of North

Carolina have recently been subjected to just such an occurrence. Used transformer oil containing large quantities of Aroclor 1260 was dumped along approximately 500 km of highways in a dozen counties surrounding Raleigh during July and August 1978. Advantage was taken of the opportunity to take air samples along the spills and the surrounding areas.

One use of PCB has been in the ballast of fluorescent lights. Because of their long life and economy, fluorescent lights are used quite often for institution, factory and business lighting. For that reason, fluorescent light ballasts and rooms containing fluorescent lights were included in this study.

For use as controls, two sites with no suspected PCB contamination were also monitored. These were a small goat farm near Apex in Wake County and land behind the U. S. Environmental Protection Agency Environmental Research Center at Research Triangle Park in Durham County.

Several potential sources were not surveyed during this study for various reasons. Incinerators were not sampled because there are no municipal incinerators in use in this area. Recent data¹³ indicate that incinerators can indeed release large quantities of PCB. Data were collected at sewage sludge incinerators in Kansas and Missouri, an industrial incinerator in Texas and municipal refuse incinerators in Florida. The investigators quantified the PCB as decachlorobiphenyl in all cases. The refuse incinerators released 2 to 34 $\mu\text{g}/\text{m}^3$ into the air while the industrial incinerator released from 0.7 ng/m^3 to 0.3 $\mu\text{g}/\text{m}^3$ although that incinerator was burning fluids containing 10-17% PCB at the time of sampling. The Missouri sewage

sludge containing a significant industrial component released 200-300 $\mu\text{g}/\text{m}^3$ PCB while the Kansas sludge which was mostly domestic waste released only 4 $\mu\text{g}/\text{m}^3$ when incinerated.

Landfills near industrial centers would be more likely to contain large quantities of PCB than the ones which form part of this study. In fact, one study¹⁴ has shown that the vent gases from an above ground landfill in a Chicago suburb does contain $\mu\text{g}/\text{m}^3$ quantities of PCB. Considerations such as time, money and location made it impossible to include these in this study. Neither a capacitor manufacturer nor capacitors themselves were used for this study, because the above considerations made it inconvenient to do so. The investment casting industry still uses PCB in their lost wax process. This process would appear to be very prone to losses of PCB (mainly decachlorobiphenyl) to the environment. However, there was not a manufacturing site in the geographical area under study.

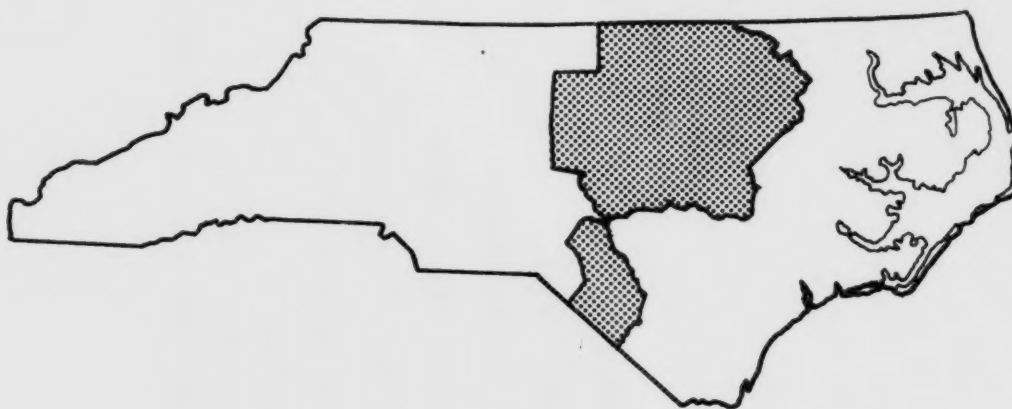


Figure 1. Sampling area within North Carolina.

Table 1
Physical and Chemical Properties of Aroclors^a

Aroclor	Appearance	Percent Cl	Average N°Cl/molecule	Vaporization rate (g/cm ² /hr)
1221	clear, mobile oil	21	1.15	0.00174
1232	clear, mobile oil	32	2.04	0.000874
1242	clear, mobile oil	42	3.10	0.000338
1248	clear, mobile oil	48	3.90	0.000152
1254	light yellow viscous liquid	54	4.96	0.000053
1260	light yellow, soft sticky resin	60	6.30	0.000009
1262	light yellow, sticky viscous resin	62	6.80	0.000013
1268	white to off-white powder	68	8.70	--
1016	clear, mobile oil	41	2.96	--

^aTechnical Bulletin O/PL-306A, Monsanto, Organic Chemicals Division, St. Louis, Missouri, 1970.

Table 2
Some Production and Use Data for Aroclors^a

Aroclor	U. S. production, 10 ³ kg			Major uses
	1969	1971	1974	
1221	230	2,007	26	capacitors, plasticizer, adhesives
1232	124	78	0	hydraulic fluids, plasticizer, adhesives
1242	20,678	9,991	2,821	capacitors, transformers, hydraulic fluid, plasticizer, adhesives, wax extenders, carbonless copy paper, heat transfer
1248	2,568	97	0	vacuum pumps, hydraulic fluid, plasticizer, adhesives
1254	4,464	2,119	2,811	capacitors, transformers, vacuum pumps, hydraulic fluids, plasticizer, adhesives, pesticide extender, inks, lubricants, cutting oil
1260	2,018	784	0	transformers, hydraulic fluids, plasticizer
1262	324	0.4	0	plasticizer
1268	136	0	0	plasticizer, wax extender
1016	0	1,515	9,980	capacitors

^aSee reference 12.

SECTION III

MATERIALS AND METHODS

Air Sampling

Both low- and high-volume air samples were taken in this study. Low-volume collections were carried out with Mine Safety Appliance (MSA) Portable Pump Model S personal samplers. These small battery-operated pumps were run at 2.5 liters per minute and were used to sample total air volumes ranging from 100 to 3000 liters. Larger air volumes (3.4 to 200 m³) were sampled with Bendix Hurricane dual speed pumps at flow rates of 0.1 to 0.5 m³/minute. The Bendix pumps were operated in the field by gasoline powered generators.

The air flow through the MSA pumps was indicated by a rotameter graduated in liters per minute. Two methods were used to calibrate the pumps to within $\pm 5\%$. A bubble flow meter of 1.0 liter volume was used to measure the volume of air moved per unit time. Some of the pumps were also calibrated by displacing water from an inverted 2 liter graduated cylinder during a measured length of time. On the Bendix high volume pumps, the exhaust air was forced through a restricting orifice (supplied with the pump) and the resulting back pressure was measured by a gauge placed directly ahead of the orifice. The gauge was calibrated by the manufacturer to read directly in ft³/min air flow.

Polyurethane foam has been shown to be an efficient collector of heavily chlorinated hydrocarbons, particularly the higher molecular weight Aroclors.¹⁵ It is also inexpensive, easy to handle, and can be effectively

cleaned to provide low background levels.⁹ The polyurethane foam (polyether type, density 0.0225 g/cm³) was received in a large sheet and plugs of the proper sizes were cut from it. Prior to their use in the field, these plugs were Soxhlet extracted twice for periods of at least seven hours in 5% diethyl ether in hexane. The solvent from the second extraction was concentrated, eluted through an alumina column and analyzed by gas liquid chromatography (GLC) to determine the blank value. Each foam plug was given an ID number which remained the same for the entire survey period. The plugs were individually wrapped in hexane-rinsed aluminum foil for storage between uses.

Glass fiber filters, MSA #CT-75428, were cut to size, wrapped loosely in aluminum foil, heated to 315°C in a muffle furnace overnight to remove any organic material, and placed in a desiccator until use.

The 10 cm filter holder that is standard equipment on the Bendix Hurricane pump was modified by epoxying a cylindrical chamber, 25 cm long x 5 cm i.d., behind the filter holder. Two foam plugs, 5.5 cm diameter x 8 cm thick, were placed in the chamber and a 10 cm diameter glass fiber filter was placed in front of them in the filter holder. The ends of the holder were covered with hexane-rinsed aluminum foil for transport to the sampling site. At the site, the sampler was connected to the Bendix pump by a 7.6 m length of Flexaust[®] CWC hose and located upwind of the pump and generator exhaust.

A glass tube, 2 cm in diameter and 7.5 cm long (tapered the last 3 cm), was used for the sampling cartridge with the MSA pumps. A small foam plug, 4 cm long x 2 cm dia. was placed in this tube and the entire tube was

wrapped in hexane-rinsed foil for transport. For sampling, the tube was connected to the MSA pump by a length of Tygon[®] tubing.

After the sampling period was completed the glass fiber filter and the foam plugs were individually wrapped in aluminum foil until analysis. Plugs and filters carried to the field along with those used for sampling served as controls.

Analytical Methods

Air Samples. Upon returning to the laboratory, the large foam plugs and filters were placed individually into Soxhlet extractors with 300 ml of 5% diethyl ether in hexane and extracted for approximately 16 hours (3 cycles/hour). The small plugs were placed in smaller Soxhlets with approximately 200 ml of hexane and were extracted for at least seven hours (6 cycles/hour). The extracts were concentrated to a volume of less than 1 ml using a Büchi rotary evaporator and an Organomation N-evap[®] and were cleaned up by alumina column chromatography.

Basic alumina (60 mesh), obtained from Alfa Products, was weighed into a flask, distilled water equal to 6% by weight was added and the flask was stoppered and shaken well. The adsorbent was allowed to equilibrate for at least 15 hours before use. Any of this mixture not used within two weeks was discarded. For chromatography a wad of pre-extracted glass wool was placed in the bottom of a Chromaflex[®] column (7 mm i.d. x 22 cm long, Kontes #42100) and washed with 10 ml hexane. The column was then packed to a depth of 17 cm with alumina. The sample was added to the column, eluted with 15 ml hexane and the eluate was concentrated to a suitable volume for GLC analysis.

When necessary, sample extracts were fractionated by silicic acid column chromatography to separate PCB from chlorinated pesticides (especially from technical chlordane residues which were present in many samples). Mallinckrodt AR silicic acid (100 mesh) was prepared for use by heating for at least seven hours at 130°C and then cooling to room temperature in a desiccator. After cooling the silicic acid was weighed into a bottle and 3% distilled water was added. The bottle was sealed tightly, shaken well and placed back in the desiccator for at least 15 hours. Any of this deactivated silicic acid not used within a week was discarded. Columns were prepared by placing 3 g of silicic acid in a Chromatoflo[®] column (9 mm i.d. x 25 cm long, Pierce #29020) equipped with a Teflon[®] mesh support membrane (Pierce #29268), lower end plate, adapter and a 500 ml solvent reservoir (Ace #5824-10). The column was washed with hexane, the sample which had been concentrated to less than 1 ml was placed on the column and 130 ml of hexane was added to the reservoir. Nitrogen pressure was applied to the column to increase the flow to approximately 3 ml per minute. The eluate was collected in three fractions. The first (0-30 ml) contained all of the Aroclor 1254 and most of the Aroclor 1242. The second fraction (30-50 ml) contained the remainder of the Aroclor 1242 and the early eluting peaks of technical chlordane. The final 80 ml fraction contained the rest of the technical chlordane, including all of the cis- and trans-chlordane. The volumes of these fractions were adjusted and the samples were analyzed by GLC.

The hexane used throughout the study was pesticide quality obtained from Burdick and Jackson. The diethyl ether was analytical reagent grade (Mallinckrodt #0850, containing 2% ethanol).

All samples were analyzed by electron capture GLC. The instrument was a Tracor 222 with a linearized Ni⁶³ detector. The columns used included: 3% OV-225 on Supelcoport[®] 80/100 mesh; 3% OV-1 on Chromosorb[®] W HP 80/100 mesh; and 4% SE-30/6% OV-210 on Gas-Chrom[®] Q 100/120 mesh. All columns were 6 mm i.d. and 1.8 m long. Off-column injection was practiced at all times. The detector temperature was 295°C, the oven temperature was 200°C and the transfer lines and inlet were maintained at 220°C. Nitrogen was used as the carrier gas at a flow rate of 85 ml/min for the SE-30/OV-210 column and 70 ml/min for the other two columns.

Aroclor standards were obtained from the Pesticide Repository, U. S. Environmental Protection Agency, Health Effects Research Laboratory, Research Triangle Park, North Carolina. The standards were made by dissolving the Aroclor in benzene and making dilutions with hexane. Stock solutions were stored in brown bottles at -10°C. Working standards were remade periodically from these and were stored under refrigeration when not in use.

Soil Samples. Surface (top 7 to 10 cm) soil samples were collected in the vicinity of the transformer manufacturer and placed in pre-cleaned glass and metal containers. Upon returning to the laboratory, the soil was dried in a vacuum oven overnight at 110°C, put through a 120 mesh sieve and weighed into extraction thimbles. The samples were extracted in Soxhlet extractors using either 300 ml of 1:1 hexane/acetone as recommended by the U.S. EPA Manual of Analytical Methods¹⁶ or 300 ml of 5% diethyl ether in hexane. Re-extraction of the samples and extraction of soil fortified with PCB standards showed that the 5% ether extraction was just as effective at removing PCB from the soil as the acetone/hexane but did not produce as

many interfering peaks in the gas chromatograms. Duplicate analyses showed that with the acetone/hexane extraction $47 \pm 3\%$ of the Aroclor 1242 and $93 \pm 6\%$ of the Aroclor 1254 were recovered. Using the ether/hexane mixture, recoveries were $65 \pm 3\%$ for Aroclor 1242 and $99 \pm 12\%$ for Aroclor 1254.

PCB Quantification. Since Aroclors are combinations of many isomers and congeners, the GLC elution gives a multi-component chromatogram. This makes quantification a much more complicated task than would be the case for a single component pollutant. The method chosen for identifying and quantifying the PCB sample extracts was based on the total peak height of the largest peaks present in the gas chromatographic "fingerprints." The number of peaks used varied from seven for Aroclor 1254 to thirteen for Aroclor 1260 (Figure 3).

The elution pattern for a sample extract that was not taken near a source of PCB emission resembled that of a combination of Aroclors. Since different Aroclors contain many of the same isomers, it was necessary to assign a cut-off for one Aroclor and a beginning for another. For example, the last two major peaks of Aroclor 1242 have the same GC retention time as the first two major peaks of Aroclor 1254 on the SE-30/ OV-210 column. These last two peaks were generally quantified as part of the Aroclor 1254.

Quality Control

Foam plug cleanup. Before being used for high volume samples, each individual large polyurethane foam plug was extracted and the extract was eluted through an alumina column and analyzed by GLC to determine its blank value. The alumina removed early GLC eluting components present in the diethyl ether and components present in the foam itself which interfered

with the analysis of the Aroclors. Figure 4 shows an air sample extract before and after alumina cleanup. At various times during the course of this survey the plugs were re-extracted after use to determine whether there was PCB buildup in the foam. When sampling at the location of a PCB spill, it was not unusual for the first plug in line to collect over 5000 ng of PCB and in one case over 2 mg was found. If even a small percentage of this amount remained on the plug until the next extraction it could add as much as an order of magnitude to what actually would be collected during that sampling. Table 4 shows the amount of Aroclor 1242 and Aroclor 1254 present on several plugs before and after sampling. The average amount of PCB was less after re-extraction but it is not a statistically significant. It can be seen that there is negligible PCB carryover.

The small foam plugs used with the MSA samplers were also pre-extracted with 5% diethyl ether in hexane. They were then re-extracted, this time with hexane alone, and the extracts were concentrated and analyzed by GLC. The smaller size of these plugs resulted in lower blank values than the large plugs had, but this advantage was lost in sampling due to the much smaller volume of air pulled through them during a sampling period. Besides having lower values, these plugs also had much less variation in the background level (9 ± 1 ng Aroclor 1242, 12 ± 2 ng Aroclor 1254 and 12 ± 5 ng Aroclor 1260). Therefore, only the average blank was subtracted. Plugs re-extracted after use indicated total removal of the PCB during a single extraction.

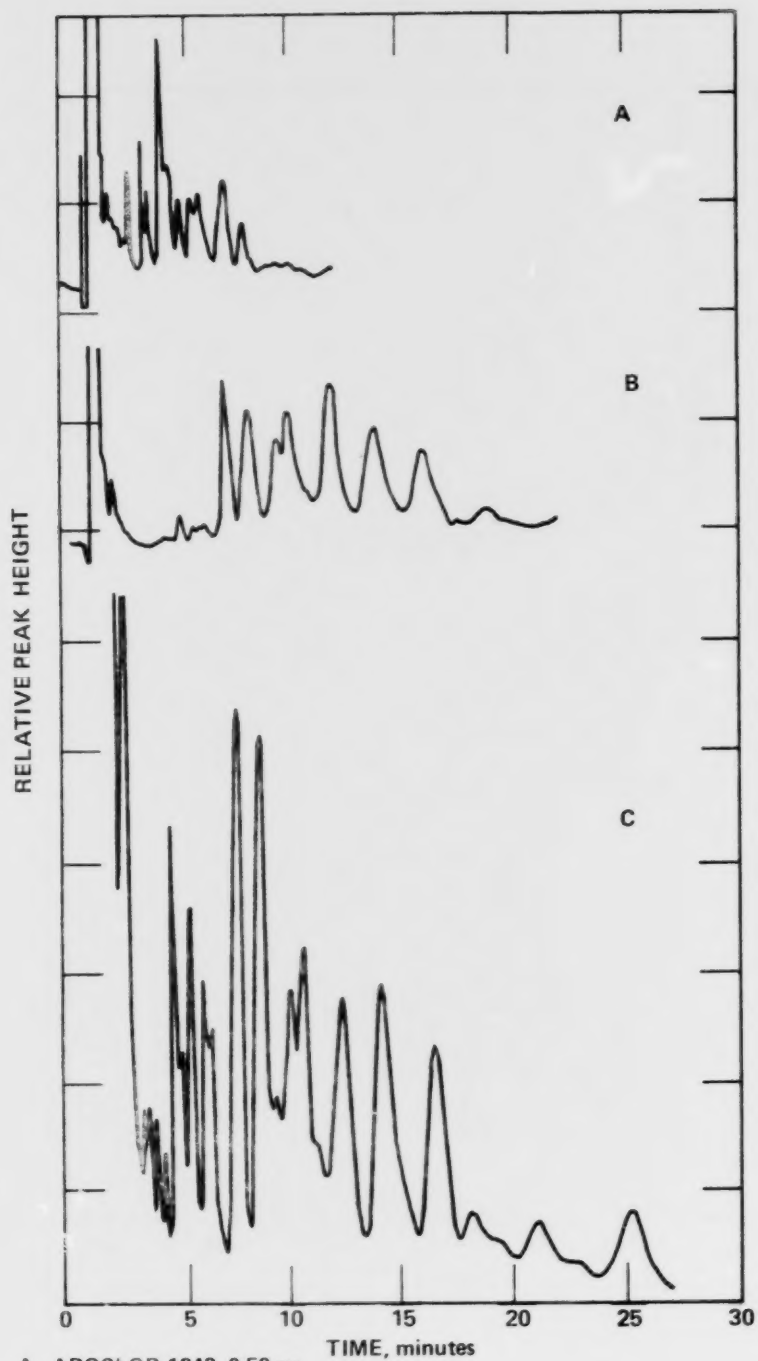
Recovery efficiency. The efficiency of the recovery process was checked by spiking foam plugs with Aroclor standards and then carrying them

through the sample extraction and cleanup procedure. A syringe or pipette was used to fortify the small plugs with a known amount of Aroclor 1242 and Aroclor 1254 in hexane. After allowing the hexane to evaporate, the plugs were extracted in the usual manner and the extracts were concentrated, run through alumina and analyzed. Four small fortified plugs gave $77\% \pm 11\%$ recovery for the Aroclor 1242 and $100\% \pm 18\%$ for Aroclor 1254 when spiked with 100 ng of each of these standards.

The large foam plugs were fortified with a mixture of five different PCB isomers that are components of commercial Aroclor mixtures. After the mixture was syringed into the plugs, the samples were Soxhlet extracted, cleaned up by alumina chromatography and analyzed by GLC. The recoveries of the Soxhlet extractions, the alumina column procedure and a combination of the extraction and concentration steps were also checked to determine any losses during the separate steps of the procedure. The results of these studies, shown in Table 5, indicate that the greatest loss (least accuracy) was during the rotovap step.

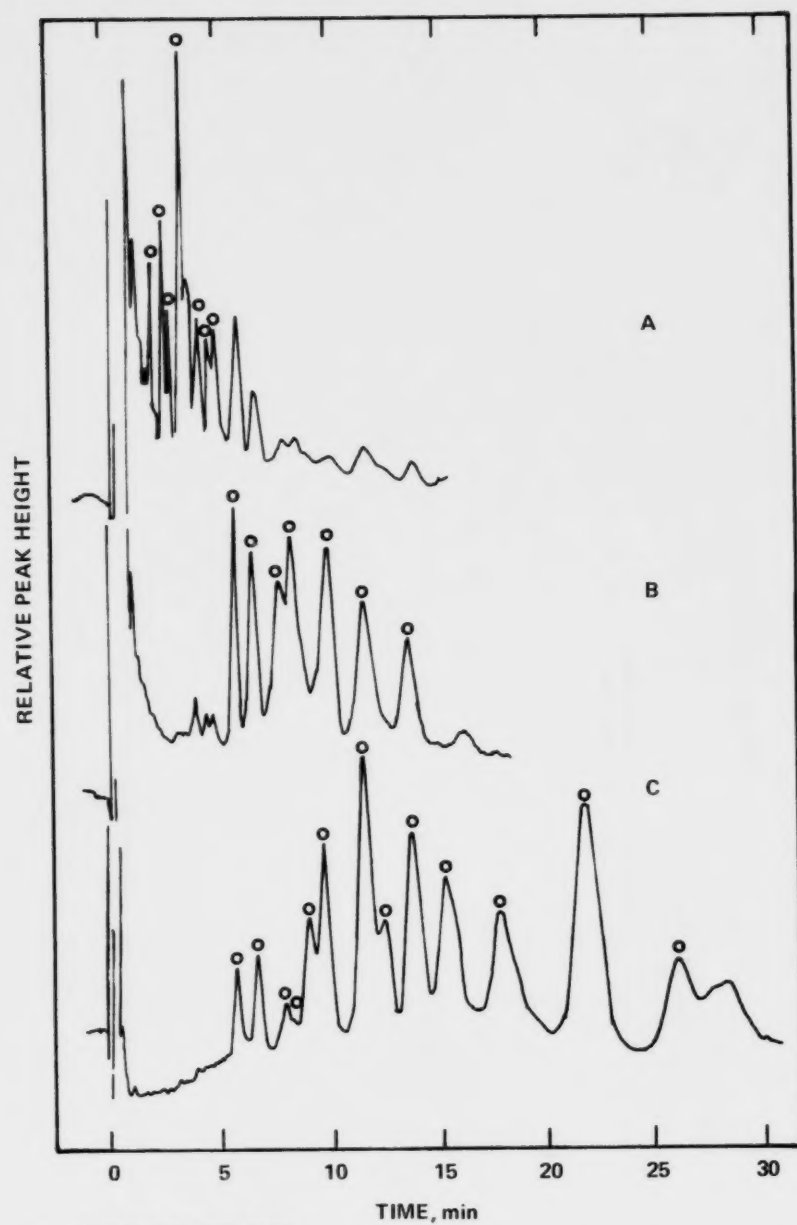
Sampling precision. The accuracy and precision of the final values generated depend on the accuracy with which the actual air flow rate is known, the collection efficiency of the sampling medium and the analytical accuracy in the laboratory. The flow rate can, and usually does, change during the sampling period due to particulate build-up on the filter, power fluctuations in the generator or pump, and battery drain in the case of the battery operated MSA samplers. Through calibration, the air flow rate of the pumps can be accurately determined to within 5% and readings can be taken during operation, so the greatest error or deviation is in the analytical

procedure and not the sampling step. Billings et al.¹⁷ found that the relative standard deviation of the analysis of triplicate air samples was about the same as the precision obtained in analyzing test mixtures of PCB and pesticides. When four MSA samplers were run overnight side by side in the same laboratory and the samples were carried through the analytical procedure at the same time, the results showed that the overall method had a relative standard deviation of 17% (Table 6).



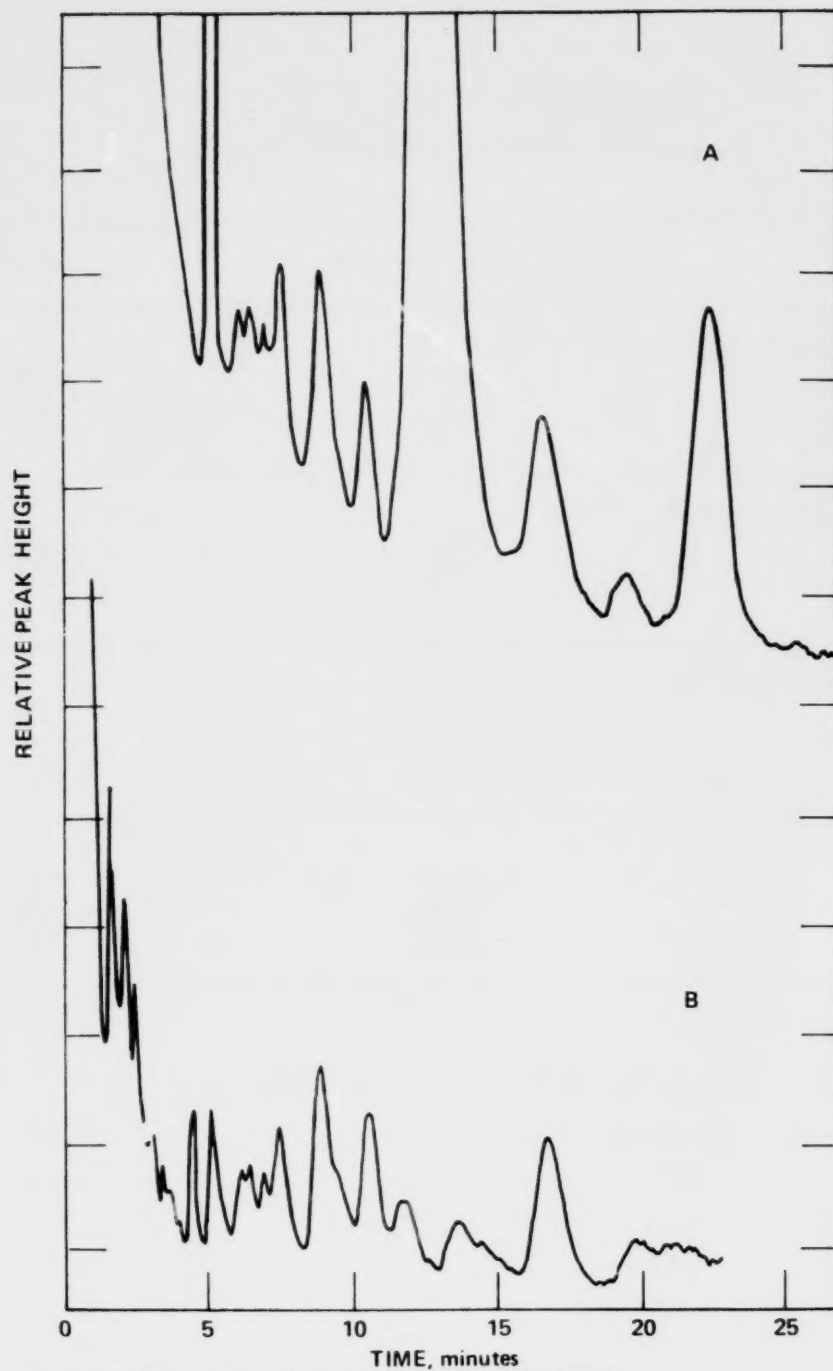
- A. AROCLOR 1242, 0.50 ng
B. AROCLOR 1254, 0.50 ng
C. AMBIENT AIR SAMPLE EXTRACT, 5 μ l INJECTION FROM 1 ml

Figure 2. Chromatograms of ambient air sample extract and aroclor standards, SE-30/OV-210.



- A. AROCLOR 1242, 0.50 ng
B. AROCLOR 1254, 0.50 ng
C. AROCLOR 1260, 0.50 ng

Figure 3. Chromatograms showing peaks used in quantifying PCB, SE-30/OV-210.



A. BEFORE ALUMINA CLEANUP, 1.3 ml, 5 μ l INJECTION
B. AFTER ALUMINA CLEANUP, 1.2 ml, 5 μ l INJECTION

Figure 4. Chromatograms of personal monitoring air sample taken at Inez, N.C., SE-30/OV-210.

Table 3
Recovery of PCB from Spiked Soil Samples

Sample	ng Aroclor 1242	ng Aroclor 1254
Acetone:hexane, ^a unspiked		
(1)	1044	1592
(2)	305	957
X	674	1274
Acetone:hexane, spiked ^b		
(1)	1564	3253
(2)	1665	3029
X	1614	3141
Ether:hexane, ^c unspiked		
(1)	729	2250
(2)	541	1607
X	635	1928
Ether:hexane, spiked ^b		
(1)	1979	4161
(2)	1874	3655
X	1926	3908

^a50% acetone in hexane

^bFortified with 2000 ng each Aroclor 1242 and Aroclor 1254

^c5% diethyl ether in hexane

Table 4
Efficiency of PCB Removal from Foam Plugs During Extraction

Plug I.D.	ng Aroclor 1242			ng Aroclor 1254		
	Before	Run ^a	After	Before	Run ^a	After
fp 22	62	1600	43	97	2700	120
fp 20	69	1400	25	100	1600	35
fp 14	31	83	48	45	97	72
fp 17	47	720	32	180	320	41
fp 4	67	8100	37	160	5400	45
fp 15	120	900	50	120	1700	54
fp 1	73	-	56	53	140,000	150
$\bar{x}$	67		42	110		75
s	27		11	49		45

^aPCB collected during sampling period.

Table 5
Efficiency of Extraction and Cleanup

PCB	ng of spike	% recovery, mean ^a			Extraction and Rotovap (4)	Alumina column (4)
		Total procedure (8)	Extraction (4)			
4,4' DCB	10,000	88	116	83	107	
2,4',5 TCB	1,000	90	110	85	106	
2,2',5,5' TCB	1,000	88	108	85	104	
2,2',4,5,5' PCB	1,000	88	108	87	100	
2,2',4,4',5,5' HCB	1,000	86	109	94	88	

^aNumber of replicate samples given in parentheses

Table 6
Replicate Samples of PCB Collected Simultaneously

Sample	Total air volume	ng/m ³ Aroclor 1242	ng/m ³ Aroclor 1254
1	2.3 m ³	143	109
2	2.4 m ³	186	118
3	2.4 m ³	198	135
4	2.4 m ³	211	159
$\bar{X}$		184	130
s		29.5	22
RSD		16%	17%

SECTION IV

PCB IN INDOOR AIR

As was noted in the introduction, fluorescent lighting has been and continues to be a very popular method of providing light in factories, businesses and institutions. Fluorescent fixtures manufactured before 1972 often incorporated PCB-containing ballasts and because these ballasts have a very long life (estimated at 12 years by the IES Lighting Handbook, 1966),¹⁸ many of these are still in use at the present time. However, very little work has been done on measuring the levels of PCB in indoor air.

Staiff et al.¹⁹ made some measurements in 1974, using two different methods of trapping the PCB. One method was to treat nylon screens with ethylene glycol and expose them for a given time period. PCB collected in this manner was measured in $\mu\text{g}/\text{m}^2$ of fabric area and only very rough correlations with air concentration could be made. The second, more accurate, method used was drawing air through ethylene glycol in midjet impingers. This method had a lower limit of detection of $0.5 \mu\text{g}/\text{m}^3$ for PCB. Neither of these methods gave very satisfactory results, especially considering that the proposed NIOSH criterion of $1.0 \mu\text{g}/\text{m}^3$ time-weighted average for maximum exposure in workplace air.⁴ They measured approximately $100 \mu\text{g}/\text{m}^3$ of Aroclor 1242 one meter below the ballast immediately after burnout, approximately $40 \mu\text{g}/\text{m}^3$ three days later, and "several weeks later" the concentrations were below the detection limit.

During this study air samples were taken in laboratories with covered and uncovered fluorescent fixtures, in offices with covered fixtures and in several homes in rooms with and without fluorescent lighting. There was also an opportunity to monitor a room containing a burned out PCB-containing light ballast.

Laboratories and Offices

The two buildings sampled were the Monsanto Triangle Park Development Center (site A) at Research Triangle Park, North Carolina, and the Physical Sciences Center, University of South Carolina, Columbia, South Carolina (site B). The samples were collected during 1977 and the first half of 1978.

The ambient level of PCB outside of site A (laboratories with uncovered fixtures) averaged 18 ng/m^3 calculated as Aroclor 1242 plus Aroclor 1254. Inside two different laboratories the level averaged 217 ng/m^3 and contained approximately equal amounts of Aroclor 1242 (55%) and Aroclor 1254 (45%). Levels in the laboratory with the covered fixtures (site B) averaged 208 ng/m^3 while the ambient air at that location averaged approximately 4 ng/m^3 . The two offices tested were also located at site A. PCB concentrations within the offices averaged 96 ng/m^3 .

On March 31, 1977, a fluorescent light ballast burned out in an office at site A. The ballast was replaced almost immediately but was left in the room overnight while an air sample was collected. The ballast was removed and disposed of the next morning. At regular intervals after this, air samples were taken overnight in the same location in that room. The results are shown in Table 7. While the ballast studied by Staiff *et al.*¹⁹ contained

only Aroclor 1242, the one in this study released a PCB mixture resembling equal amounts of Aroclor 1242 and Aroclor 1254.

These measurements indicate that when fluorescent light ballasts burn out, quantities of PCB are released which can elevate the levels in indoor air for periods of several weeks. After three, or at most four, months the levels receded to what must be considered background for indoor air. The fluctuations in PCB concentration after that time are probably due to daily variations or, more likely, to limits in sampling precision. For further discussion of this point, see the section on quality control.

Houses

The houses used in this study located were in Raleigh, Durham, Cary, and Lumberton, North Carolina. The samples were collected between April and August, 1978. Five of these houses had fluorescent lights been installed prior to 1971 in the kitchens while the other four contained only incandescent lighting.

The data from the nine houses included in this study (Table 8) showed some unexpected results. The PCB levels in the kitchens of these houses ranged up to six times those found in offices. The kitchens also consistently had higher concentrations than the other rooms of the same house. The house with mean levels of 530 ng/m^3 in the library and 620 ng/m^3 in the kitchen was sampled on two separate occasions and the results were consistent. Even though 95% of the PCB present resembled Aroclor 1242 there did not seem to be an obvious point source producing these levels. The average level of PCB, again quantified as Aroclor 1242 plus Aroclor 1254, was slightly higher for kitchens with fluorescent lighting, but this difference was not statistically significant.

The results of the air sampling show that indoor levels of PCB are considerably higher than normal outdoor levels. They also show that the levels in laboratories tend to be higher than those in offices. Since the laboratory with covered fixtures had a level comparable to that in the other laboratories and not to those in the offices, it appears that the difference may not be related to the lights but instead to the equipment present. The offices tested did not contain any electrical equipment which might contain capacitors whereas all three of the laboratories did. It might be noted that the ratio of Aroclor 1242 to Aroclor 1254 in the rooms was the same as that for the burned out ballast. This may not be indicative of the source, however, since Aroclor 1242 and Aroclor 1254, as well as Aroclor 1221, have been used in the manufacture of capacitors.¹ The similar levels present in the houses with and without fluorescent lighting also indicate that the other appliances and electrical equipment found in kitchens rather than the lights may be contributing the PCB to the atmosphere.

The question of air circulation (type of air conditioning, if any) might come up in trying to determine the difference in PCB levels. The only house included in the study that did not have central air conditioning was the one in Lumberton. The kitchen of this house contained PCB concentrations slightly below the median for the other kitchens monitored.

Table 7

Decline of Airborne PCB in a Room After Burnout of Light Ballast

Day	Aroclor 1242 ng/m ³	Aroclor 1254 ng/m ³
0 = burnout	5740	5860
31	530	730
61	250	249
95	116	111
122	64	64
283	119	93
334	114	98
377	73	88

Table 8
Airborne PCB Levels in Private Dwellings

All quantities are calculated as Aroclor 1242 plus Aroclor 1254					
House	Room	ng/m ³	Room	ng/m ³	Room
Cary house 1 house 2 house 3 house 4	kitchen	476			
	kitchen	184			
	*kitchen	250			
	*kitchen	212	living room	39	
Lumberton					
	kitchen	241	attic	<50	bedroom
Durham house 1 house 2 house 3					
	kitchen	146	garage	64	
	*kitchen	576			
Raleigh	kitchen	255			
	*kitchen	620	library	530	
					basement
				174	121

*Indicates rooms with fluorescent lighting.

SECTION V

LANDFILLS

Since publication of Nisbet and Sarofim's 1972 paper,¹¹ several investigators have suggested that landfills and dumps are potential emission sources for PCB.^{10,12,20} Soil, groundwater and leachate have been shown to be contaminated with PCB in and around landfills,²¹ but it was not until 1977 that data was published confirming emissions into the air from landfills.

Murphy and Rzeszutko¹⁴ collected two samples on the same day from one landfill and found that the mean concentration of PCB was 3240 ng/m^3 . These samples were taken at the vent pipes of a sealed above ground landfill in the highly industrialized Chicago area. In November of the same year, Hetling *et al.*²² sampled the air above two landfills that were dump sites for General Electric capacitor facilities near the Hudson River. The ambient levels at these sites ranged from 930 ng/m^3 to 5900 ng/m^3 calculated as Aroclor 1016. These results indicate that some landfills do indeed emit very high concentrations of PCB. On the other hand, landfills in New Bedford, Massachusetts which contain over $22 \times 10^3 \text{ kg}$ of PCB were emitting only 21 ng/m^3 in January 1978 while the ground was frozen and light snow was falling. The previous summer (June 1977) 400 to 1300 ng/m^3 of PCB had been measured at the same location. As Nisbet and Sarofim had suggested, the lighter Aroclors seemed to predominate at these sites.

Landfills for predominantly residential areas that contain household trash and debris instead of industrial wastes have not been monitored up to this time. Many of the former uses of PCB (plasticizers, flame retardants, adhesives, inks, etc.) would point to their disposal at least in limited quantities in this type of landfill. This is also the most abundant type of landfill found in the area under consideration.

The present Durham, North Carolina city landfill was opened in December 1974 and was the only one in the study still in operation at the time of sampling. The old city landfill, one of three closed ones studied, was located on property adjacent to the present one. It was in operation from 1960 until 1974 when the new one was opened. The Raleigh, North Carolina landfill, which ceased operation in 1973, was next to the state mental hospital and directly across the highway from the state penitentiary in downtown Raleigh. The air samples at this site were taken at a spot that was known to have been leaking methane. The only landfill surveyed that had known PCB dumping was the Old Demolition Site in Goldsboro, North Carolina. The PCB waste material (Aroclor 1254) from the transformer manufacturer surveyed in this study was dumped here. The locations of these landfills are shown in a series of maps (Figures 5-7).

The data collected at the landfills are shown in Table 9. Also shown are data taken at two sites in Durham and Wake Counties that were used as controls. As can be seen, the PCB concentrations in the air above these landfills are slightly higher than those in the control area, but are orders of magnitude less than those in the Chicago and Hudson River studies. In contrast to the measurements made by Hetling *et al.*, Aroclor 1254 was almost as abundant as the more volatile Aroclors.

The landfill in Goldsboro did not show higher concentration of PCB than the other landfills, and actually had the lowest ambient concentration of all four landfills studied. The actual area of PCB dumping in the landfill could not be determined, so it is possible that the areas sampled toward the front half of the 200 m long landfill were not where the dumping occurred. (An automobile demolition operation prevented the sampling of the back half of the area.) The low results were still unexpected, considering the magnitude of PCB found by the other investigators.

The Raleigh landfill had at least one third more Aroclor 1242 than any other location. There is not enough data available to determine whether this is significant or just a matter of sampling variation. The Wake County levels of Aroclor 1242 are higher than the other locations, but the two control locations are actually closer together than either is to the landfills.

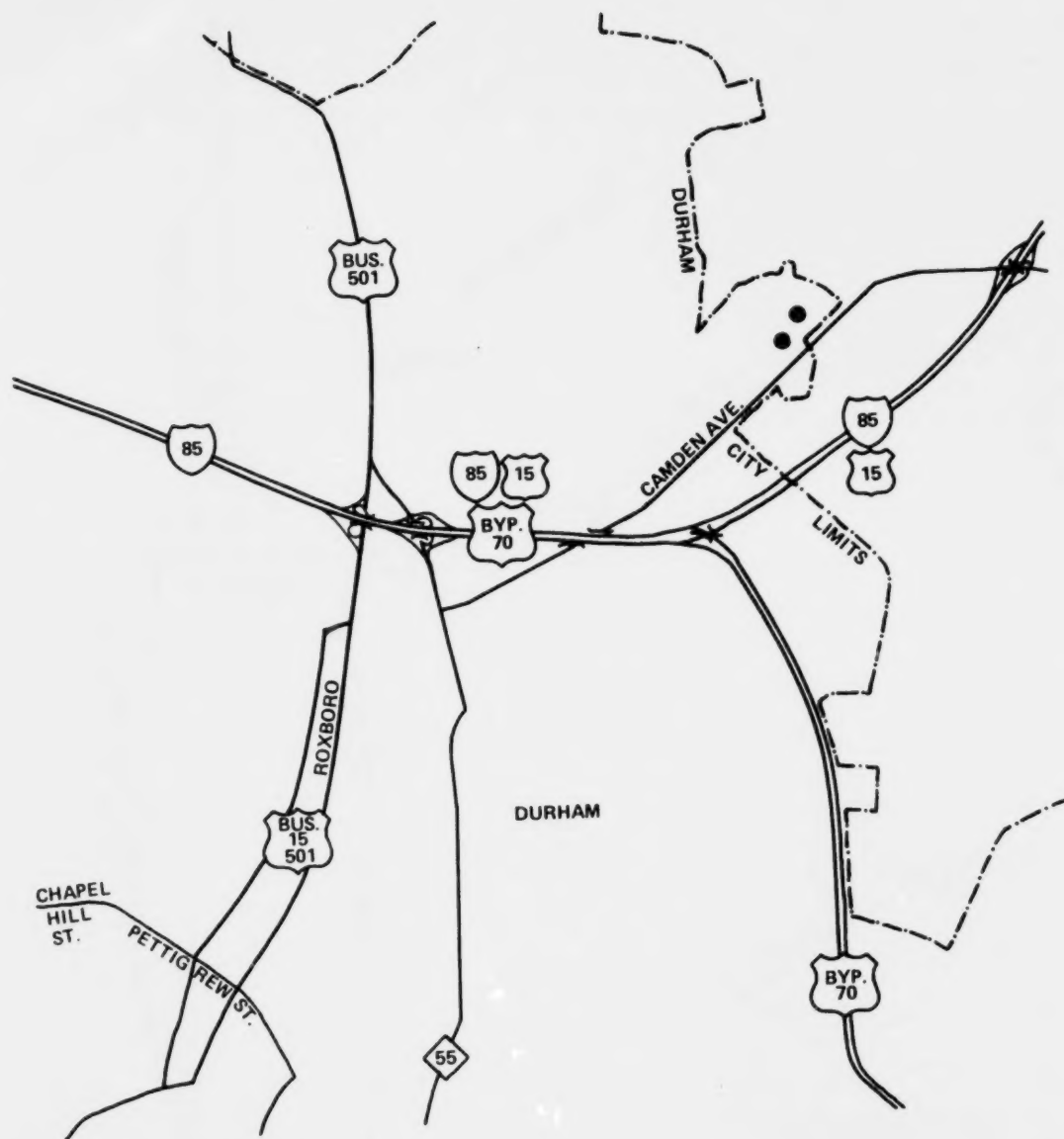


Figure 5. Locations of Durham Landfills sampled.

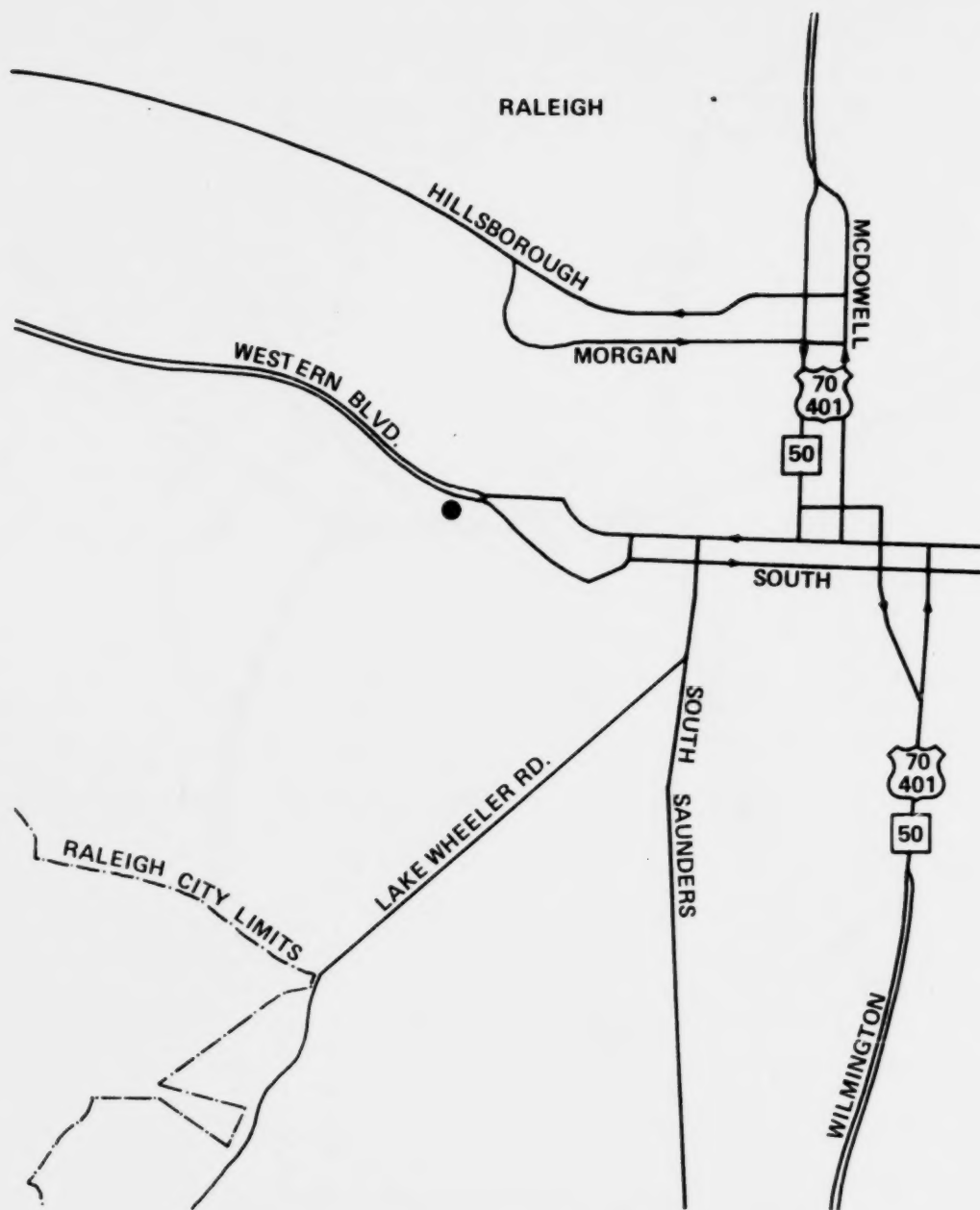


Figure 6. Location of Raleigh City Landfill sampled.



Figure 7. Location of Old Demolition Site, Goldsboro, N.C.

Table 9
PCB Concentrations in Air Over Landfills

Landfill	ng Aroclor 1242/m ³	ng Aroclor 1254/m ³
Durham, Durham Co.	9	5
Old Durham, Durham Co.	11	10
Old Raleigh, Wake Co.	18	9
Old Demolition Site, Wayne Co.	4	8
<u>Control</u>		
RTP, NC (Durham Co.)	4	9
Shadowfax Farm (Wake Co.)	12	2

All samples were collected in March 1977, except those from Wayne Co., which were collected in October 1978. All samples were taken 50 cm above the ground with the intake horizontal to the ground.

SECTION VI

ELECTRICAL SUBSTATIONS

Apparently the only monitoring near an electric power substation up until this time was done by Environmental Science and Engineering, Inc.²³ in northern Florida in 1975. Their sampler was approximately 100 m from the substation but only 20 m from a transformer storage facility. No mention was made in their report concerning orientation of sampler, substation and storage facility or of wind direction so there was no way to discriminate between emissions from the substation and the storage facility. The results were reported by chemical species (mono-, di-, trichlorobiphenyl, etc.) instead of as a particular Aroclor mixture but by adding the concentrations reported, the total appears to have approximated 52 ng/m³ of Aroclor 1016. This is higher than the 3-36 ng/m³ (calculated as decachlorobiphenyl) that the same investigators reported in urban Jacksonville, Florida, air.

Five electrical substations located in Durham County, North Carolina, were chosen to be part of this survey. Even though only about 5% of all transformers contain PCB, those that do are located primarily around buildings or transportation facilities.¹² The substations studied were chosen because of the proximity of buildings or heavily traveled highways. The five sites are indicated on the map shown below.

For this survey, one sampler was located upwind of the substation being monitored and another sampler was located downwind. Both samplers were placed outside the fence protecting the transformers and capacitors and so were approximately 30-40 m from them. At several of the sites, samples were lost on different occasions due to failure of the generators or pumps, thus reducing the amount of useful data collected. The data that was obtained are shown in Table 10.

The results indicate that there is no large scale leakage of PCB from these particular transformers and capacitors. This does not preclude power substations as emission sources, however, since the number sampled for this survey represents an almost infinitesimal percentage of the total number.

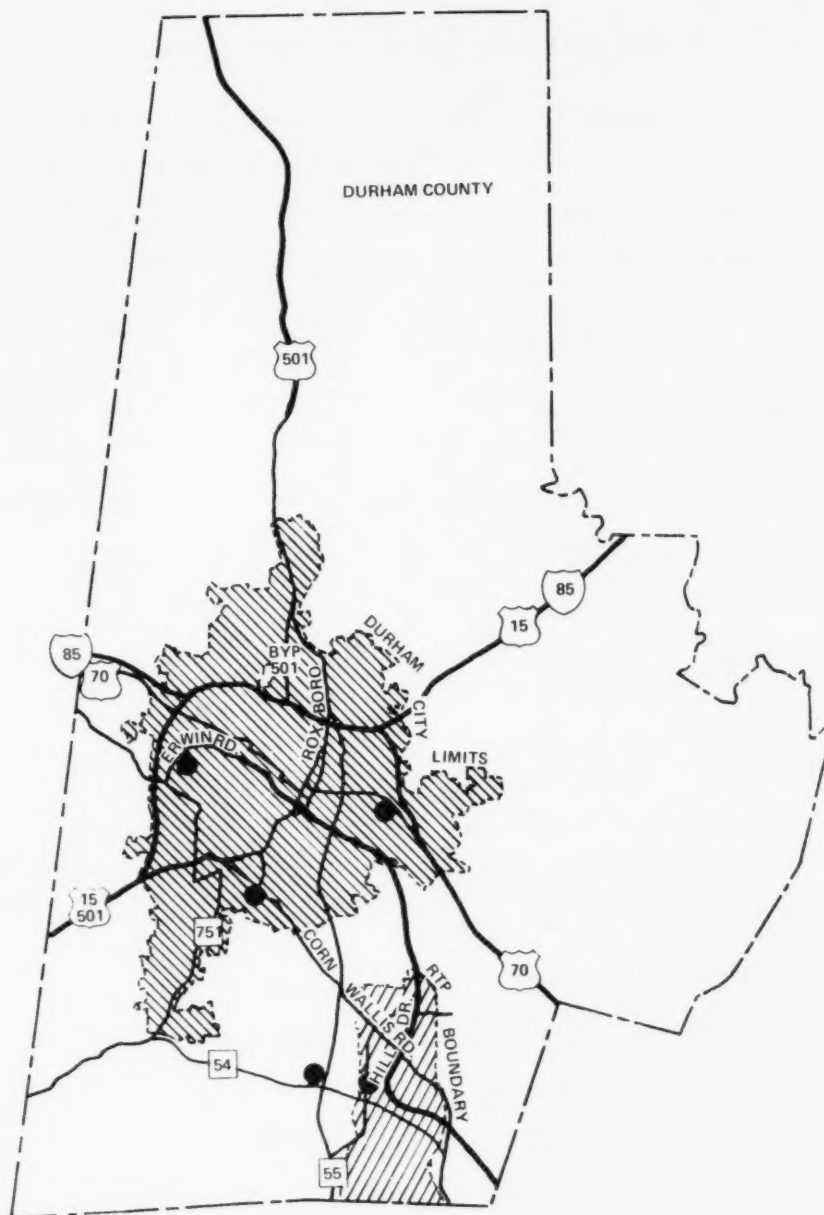


Figure 8. Locations of electrical substations sampled.

Table 10
PCB Data from Electrical Substations

Site	Date	Upwind air Concentration, ^a (ng/m ³)	Downwind air Concentration, ^a (ng/m ³)
A	5-5-77	b	47
	5-12-77	16	8
	6-10-77	10	17,18
B	5-31-78	b	25
	6-1-78	c	17
	6-9-78	11	8
	7-12-78	c	14
C	6-10-78	1	32
	7-13-78	c	41
	8-24-78	42	21
D	7-31-78	10	20
	8-29-78	8	10
E	8-1-78	c	18
	9-26-78	19	6

^aAll amounts are calculated as Aroclor 1242 + Aroclor 1254.
All samples were taken 50-200 cm above the ground with the intake horizontal to the ground.

^bSamples not taken.

^cSamples lost due to equipment failure.

SECTION VII
MANUFACTURING SITE

For some time it has been recognized that the sites of manufacture of both PCB and PCB-containing products have the potential for introducing large quantities of these chemicals into the environment. Since 1969, investigators^{14,24,25,26} have been reporting measurements of PCB concentrations in the soil and water surrounding these plants and have confirmed that they do release large quantities of PCB. Lake Hartwell in South Carolina²⁷ and the Hudson River in New York^{22,28} have both been grossly contaminated by factories on their shores. In 1976 and 1977, measurements were made of PCB levels in the air around the facilities on the Hudson River. These facilities ceased using PCB in June 1977 and almost immediately the PCB levels dropped significantly. While PCB was being used, the ambient air levels ranged from 500 to 1700 ng/m³. The average levels from July to November 1977 were below 400 ng/m³.²²

Hevi-Duty Electric, a subsidiary of Solar Basic Industries, located in Goldsboro, North Carolina, is one of the thirteen manufacturers of transformers in the United States today. They have been making and repairing large transformers at their present site since 1968. By 1971, they had begun to realize the threat of PCB to the environment and to the health of their employees and to control much more carefully the storage, use and

disposal of the large quantities of askarel used in the production of their products. Prior to 1971, they had stored the askarel in drums in an open area behind the plant. Empty drums were also kept in this area and spills in the plant area were cleaned up with rags which were then thrown into these drums. The waste material from the plant was disposed of in the Old Demolition Site, a landfill run by the city. This landfill is now buried and no PCB emissions from it were detected in this work.

Since 1971, the company has tried to reduce the contamination of PCB to a minimum. The askarel is now kept in a closed system under a nitrogen atmosphere. The soil in the old storage area which was found to contain large amounts of PCB, was dug up to a depth of 0.6 m, encased in plastic and buried in another spot on company property.

For this study, air samples were taken over a 16 month period in the area of the old PCB storage site and at 10 other sites in the vicinity of the plant. These sites are shown in Figure 9. The ideal situation would have been to collect samples at every site at the same time; however, equipment limitations prevented this. During sampling, measurements were made of soil and air temperatures. A wind rose of the area, Figure 10, was obtained from Seymour Johnson Air Force Base 6 km away, and 17 surface soil samples were collected to determine dispersal of contamination from the site and whether it could be correlated to wind direction. Tables 11 through 13 show the analytical results while Table 14 gives the meteorological data.

The data indicate that there is still a large amount of PCB present even after the major cleanup attempts at the site of the original contamination. As far as 150 to 300 m to the north and east (Sites C and H, Table 11) the aerial concentrations of Aroclor 1254 was in the 100 ng/m^3 range. At the same time, two other sites (D and K) approximately 300 m distant showed an order of magnitude less PCB, approaching background levels found elsewhere. The only air samples taken further than 300 meters were on private property about 500-600 meters to the east. The levels here all also approached "normal" levels. A series of samples taken vertically over Site A from 0.02 m to 1.8 m above ground showed no appreciable difference in PCB levels with height. This is probably due to the widespread contamination of the area, soil, air, and perhaps interior of the building nearby.

No correlation could be made of PCB concentration with air or soil temperature using the amount of data generated during this study. The levels varied greatly at the individual sites near the plant, but this may have been due to the eddy effect of the wind close to the building or to gusting on certain days.

The soil samples collected away from the immediate plant area contained larger concentrations of Aroclor 1254 than had been expected, but this was also true of the one control sample (#18). All of the values were at least one order of magnitude lower than those reported for similar distances from Monsanto's Aroclor production plant at Sauget, Illinois.²⁶

Generally, the further from the plant site the lower the PCB level in the soil. The major exception was #17, which was the Old Demolition Site where PCB wastes from the plant had been dumped previously. Two other

sites were also higher than the other samples taken at comparable distance: the sewage pumping station, site #7, which also had higher aerial levels than the other site the same distance from the plant, and site #3, which was located at the corner of the driveway used to deliver chemicals to the plant.

Overall, the results indicate little or no contamination of the air or soil beyond the property boundaries that can be traced to the askarel used by the company.

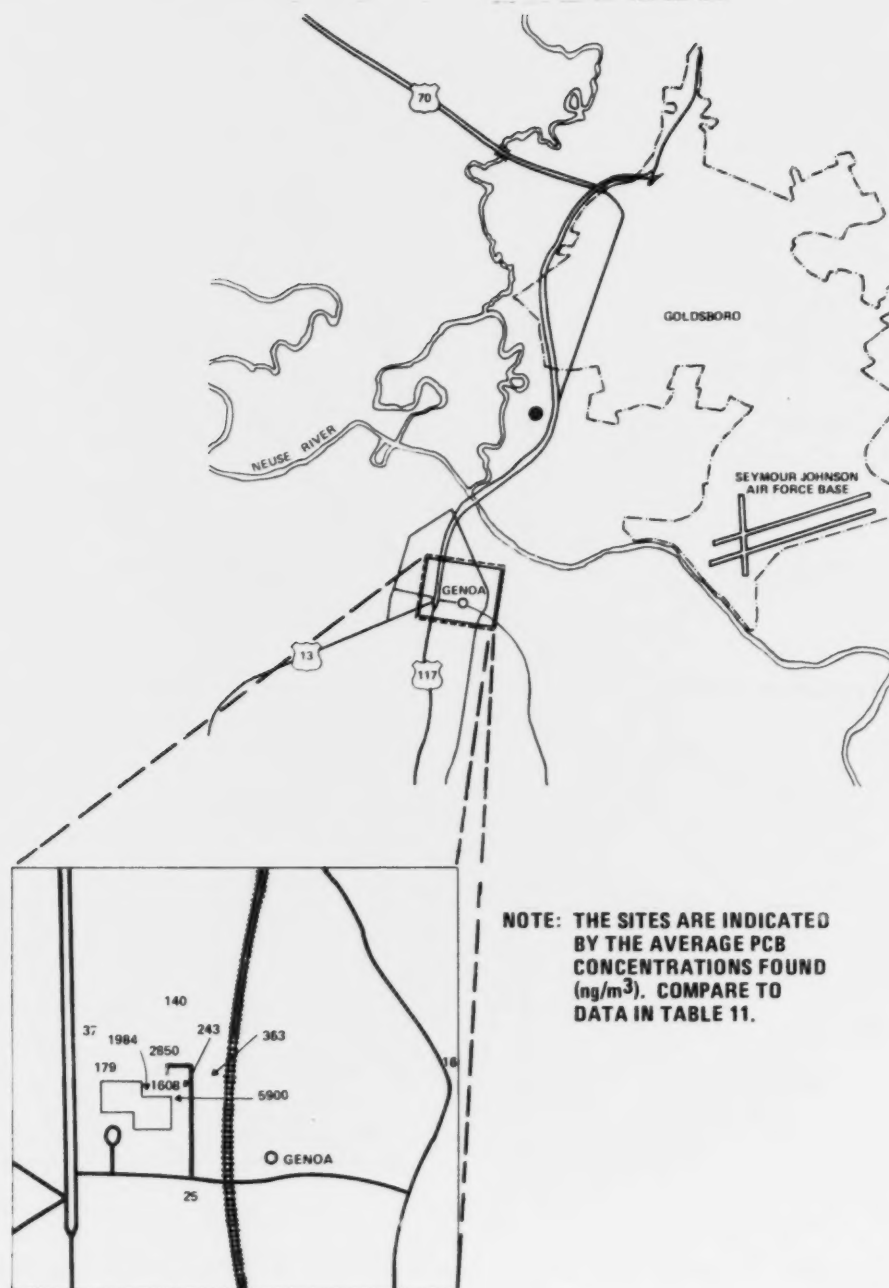


Figure 9. Ambient sampling sites in the vicinity of a transformer manufacturer.

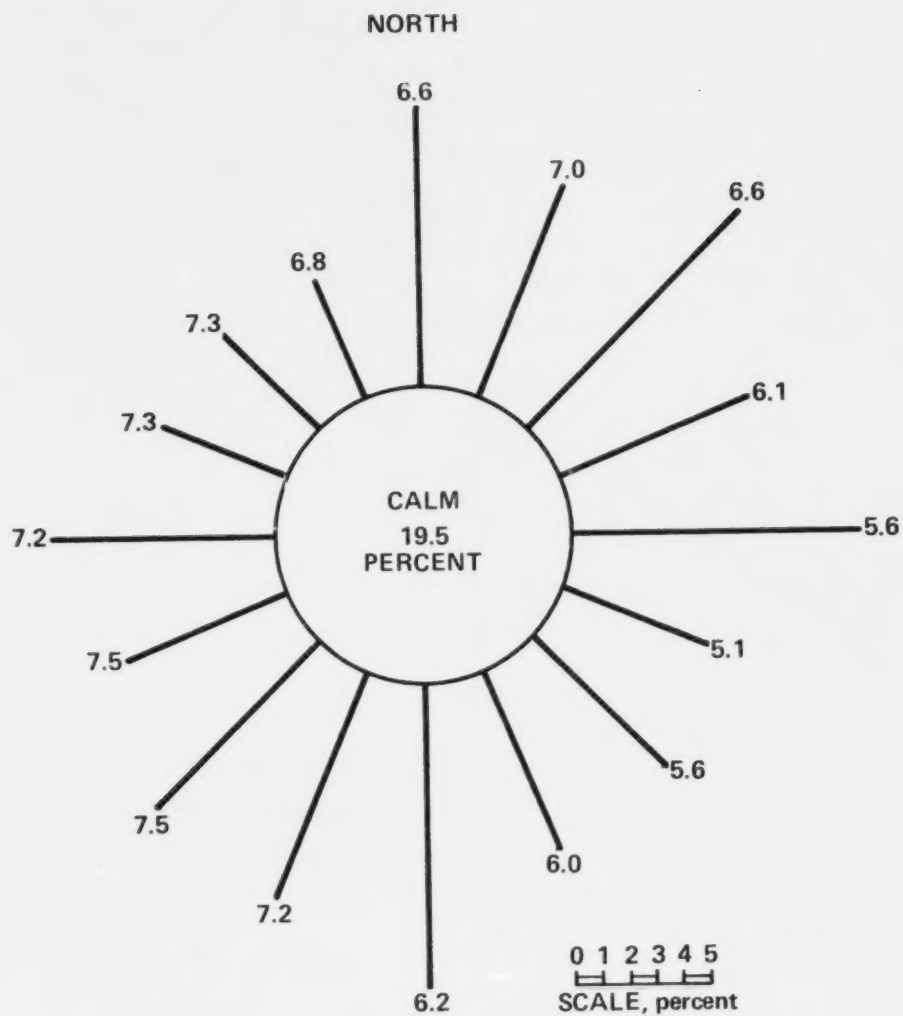


Figure 10. Annual wind rose for Goldsboro, N.C. (Mean wind speed in knots is given at barb ends, frequency of occurrence is given by barb length.)

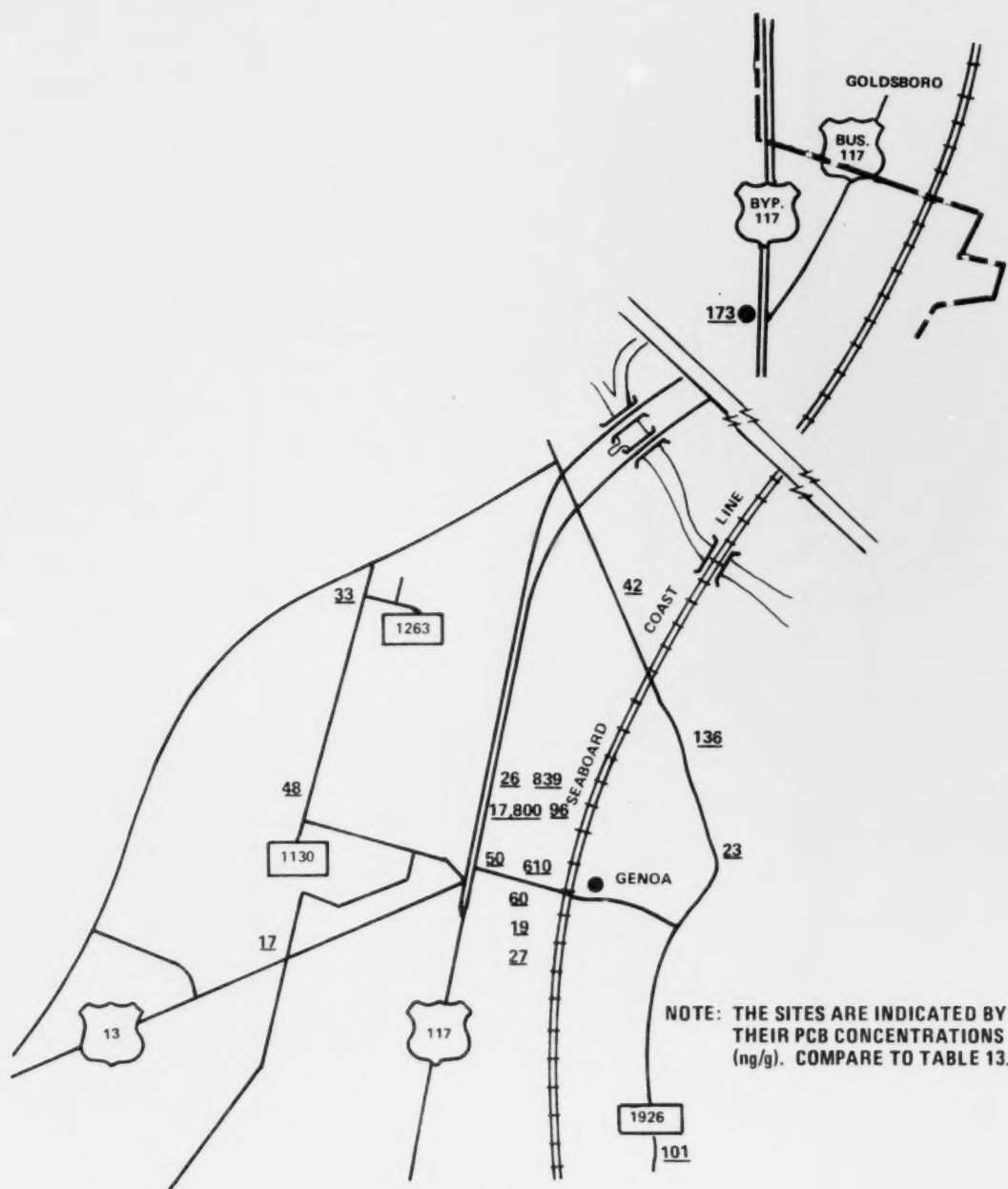
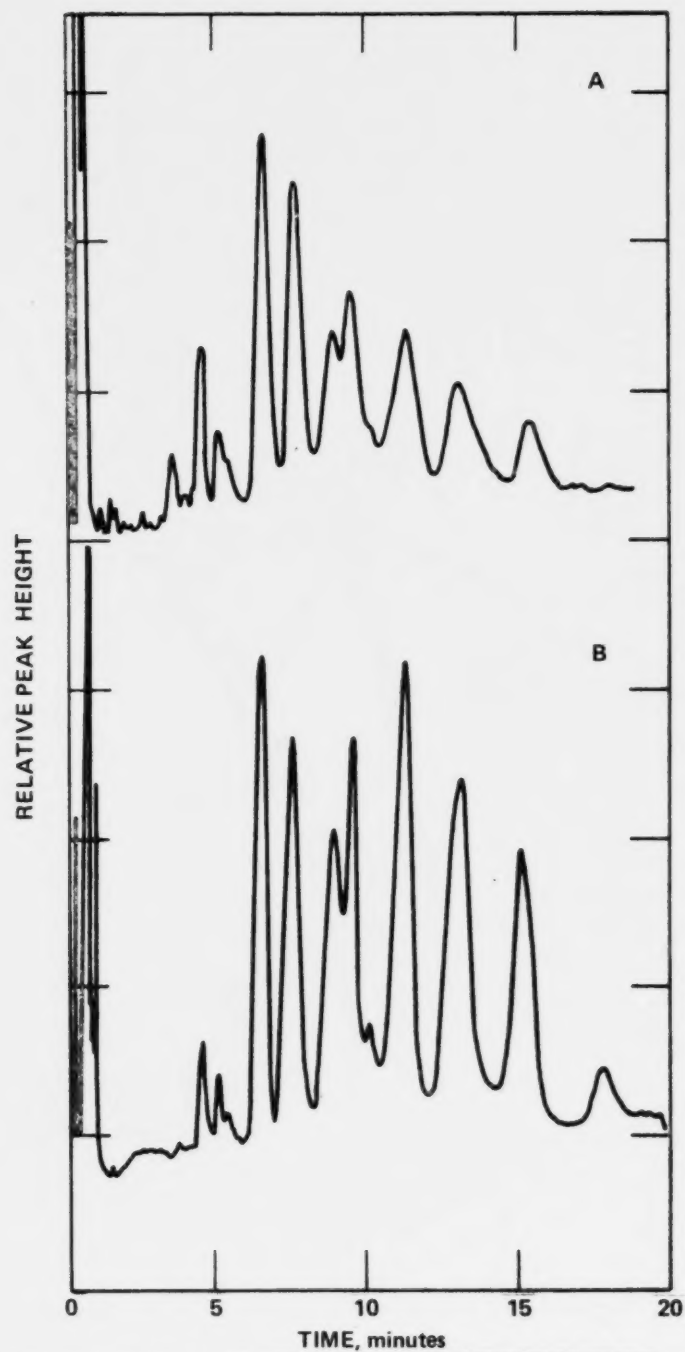


Figure 11. Soil sampling sites in the vicinity of a transformer manufacturer.



A. AMBIENT AIR EXTRACT FROM SITE H, 5 μ l INJECTION FROM 100 ml.
B. SOIL EXTRACT FROM SITE 9, 5 μ l INJECTION FROM 180 ml.

Figure 12. Chromatograms of extracts of samples collected near a transformer manufacturer, SE-30/OV-210.

Table 11

Aerial Concentrations of PCB in the Vicinity of a Transformer Manufacturer
 All samples were taken approximately 50 cm above the ground and horizontal to it

Date	A	B	C	D	E	F	G	H	I	J	K
4/14/77	2,700 ^a										
4/15/77	1,900	2,000									
5/6/77	1,500		900	67							
6/15/77			39	12							12
6/16/77	430		78								20
6/17/77	520										
8/2/77	2,900		790	72			2,800				
8/5/77	1,200		390				3,400				
3/13/78	790	3,700	40	17	210	410	720	160			
3/15/78	3,400		560		340	87	1,400	120	5,900		25
3/17/78	740		300,170	18	180	39	1,600				
$\bar{X}$ =	1,600	2,800	360	37	240	180	2,000	140	5,900	16	25

^aAll values are ng/m³ Aroclor 1254

Table 12
 PCB Concentrations as a Function of Distance from Ground Level
 Site A, August 8, 1978

m above ground	$\mu\text{g}/\text{m}^3$ Aroclor 1254
0.02	2.5
0.30	2.2
0.60	2.6
1.20	2.9
1.80	1.9

Table 13
Concentrations of PCB in Soil
in the Vicinity of a Transformer Manufacturer

Site	m from source	direction from source	ng/g Aroclor 1254
1	0	--	17,800
2	150	E	96
3	150	SE	610
4	200	S	60
5	300	S	19
6	300	SW	50
7	300	N	839
8	300	NW	26
9	500	E	23
10	500	S	27
11	500	W	17
12	500	NE	136
13	600	NW	33
14	800	SE	101
15	800	W	48
16	800	N	42
17 ^a	4,000	NE	173
18 ^b	80 km		74

^aOld Demolition Site - landfill

^bInvestigator's backyard, Raleigh, N. C.

Table 14
Meteorological Data During Sampling
at a Transformer Manufacturer

Date	Cloud Cover	Wind Speed km/hr	Wind Direction	Soil Temperature °C	Ambient Temperature °C
4/14/77	CLR	3-8	--	--	~32
4/15/77	CLR	--	--	--	~32
5/6/77	CLR	3-8	from ENE		27-35
6/15/77	SCT	3-8	20°-60°		21-27
6/16/77	HAZY	0-3	60°		17-28
6/17/77	OVC	2-6	130°-150°		22-29
8/2/77	SCT	0-10	230°-290°	30-39	23-30
8/5/77	BKN	11-18	220°-260°	33-40	28-33
3/13/78	OVC	13-21	80°-110°	12-16	13-17
3/15/78	SCT	0-16	270°-320°	10-20	11-20
3/17/77	SCT	6-29	270°-320°	12-16	4-10

SECTION VIII

PCB SPILL

During the period June 29, 1978 to August 8, 1978, 340 km of highway in 12 different counties of North Carolina had chemical wastes systematically spilled along them. Analysis of soil, plant and water samples by both the U. S. Environmental Protection Agency and the North Carolina Department of Human Resources indicated that the substance was predominantly Aroclor 1260.

On August 11, 1978, air samples were taken up and downwind at the site of a spill on State Road 1346 in Chatham County. The next day another spill site, on NC 210 in Johnston County, was sampled. At this spill, which had been covered with sand the previous week, the air on-site and in a house 30 m from the spill site was monitored. On August 16, 1978, a third site, on US 421 in Chatham County, was monitored. At this location, samples were collected at varying levels directly above the spill from 2 cm up to 1.8 m.

The North Carolina Department of Transportation placed a layer of charcoal covered by road tar over the spills in an attempt to hold down contamination of the surrounding areas until a permanent solution to the problem could be found. The Johnston County spill site was covered with this mixture on August 24 and was revisited for sampling on August 26 and September 9.

After much discussion of the various alternatives for handling the cleanup of the spill sites, it was decided to try digging up a 0.5 m wide

strip 10 cm deep and removing the dirt for disposal. Before this was done on a large scale, a 1.5 km stretch of road was to be tested to determine the feasibility of this method of removal or any hazard to residents of the area or to the personnel doing the removal work. The site chosen was NC 58 in the vicinity of Inez, Warren County.

The personnel involved in the removal wore disposable coveralls, boots, disposable plastic gloves, goggles and two stage (dust and organic vapor) respirators. Some of the workers also carried MSA personal monitors with PVC filters and polyurethane foam to trap dust and PVC vapors from their breathing zones during the dig.

In preparation for the practice dig, both indoor and ambient air at the site was monitored on September 19 and October 4. On October 5, 1978, the contaminated soil was removed and transported to a temporary holding area where it was encased in four layers of heavy duty polyethylene plastic. For the removal to proceed with as little dust as possible being generated, a hydroseeder wet down the area just before the motorgrader removed the dirt. The dirt was then collected by an Athey[®] conveyor loader which dumped it into trucks for transport to the holding area. The sweeper, preceded by another hydroseeder, swept any remaining dirt on the road back into the trench and the trench was refilled with uncontaminated soil from another location.

During this operation, MSA samplers were monitoring three of the buildings along the route of the digging operation. High volume air samples were also taken in the fields 30 m on either side of the road and at the holding area. One week after the dig, October 12, 1978, another set of

ambient and indoor air samples was collected. All of the results are shown Tables 16-18.

There is definitely an increase in aerial Aroclor 1260 concentration in areas very close to the spills along the roads. The house in Johnston County and at least one of the buildings in Warren County also had elevated levels. There is no real indication that the charcoal/tar treatment reduced the amount of Aroclor 1260 escaping into the air, though the amount seemed to go down with time since the spill. Monitoring at the dig site showed no increase of airborne PCB due to the digging. Indications are that there is no danger from air pollution to the inhabitants of the area from a cleanup operation of this type.

Personnel breathing zone measurements are given in Table 19. The highest levels of PCB to which the workers were exposed were less than the $1.0 \mu\text{g}/\text{m}^3$ PCB for an eight to ten hour day allowed under the proposed NIOSH criteria for the workplace.⁴

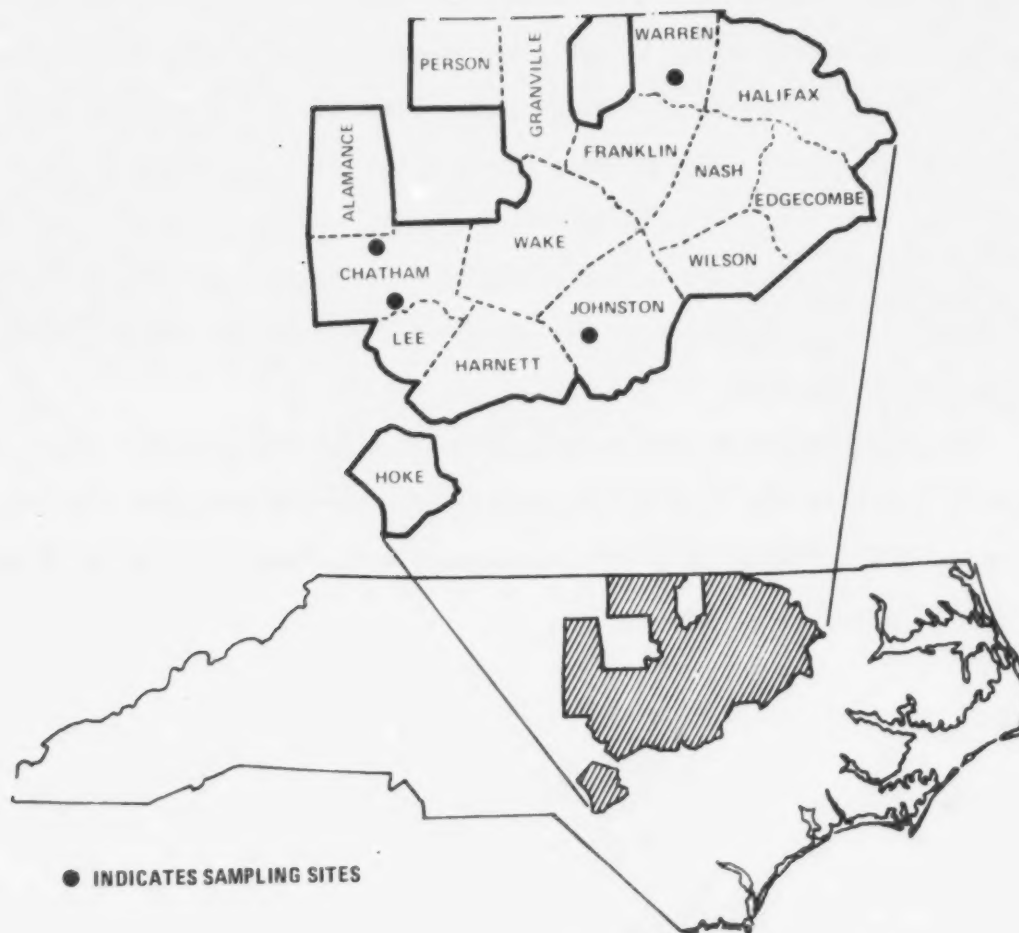


Figure 13. Area of North Carolina containing PCB spills along highways.

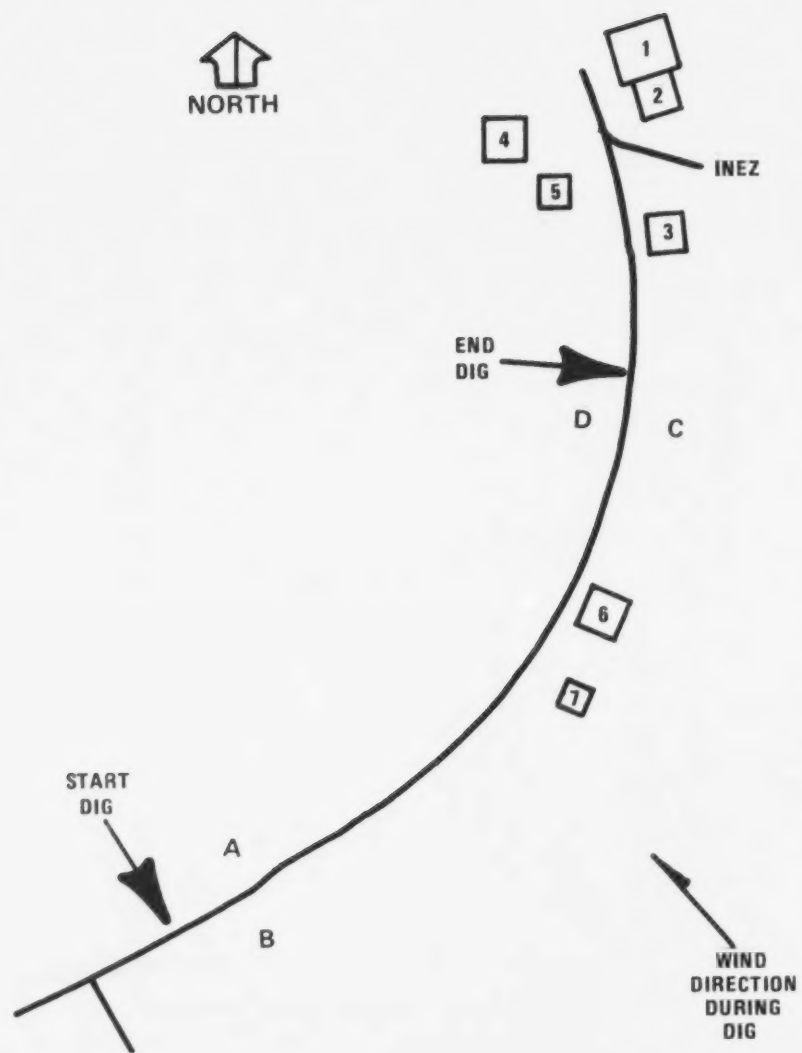
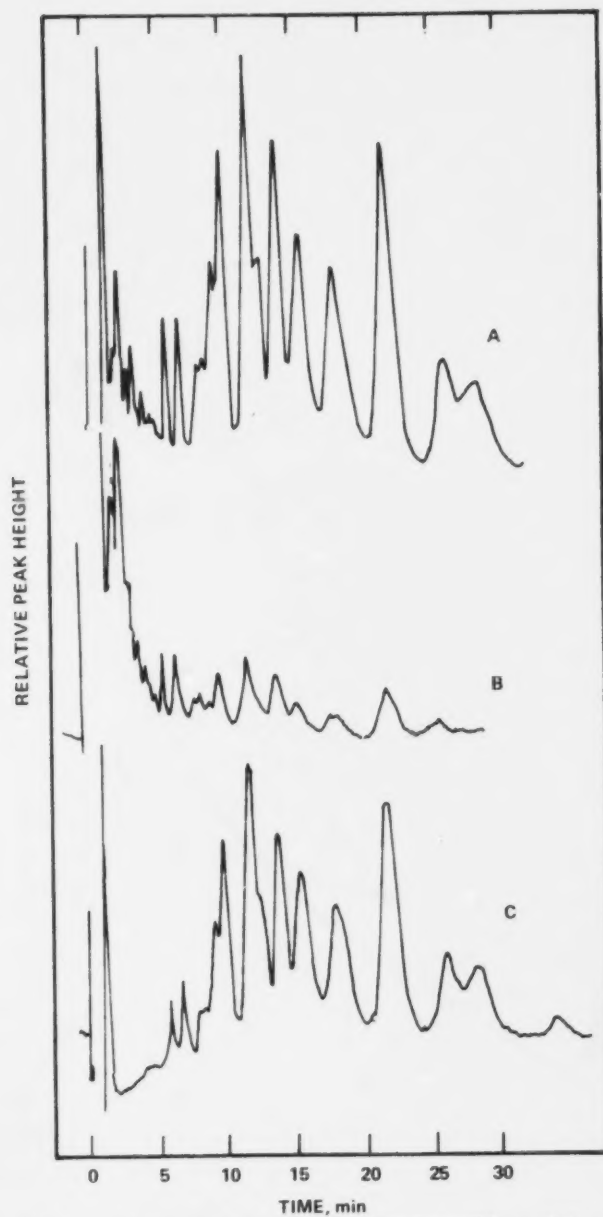
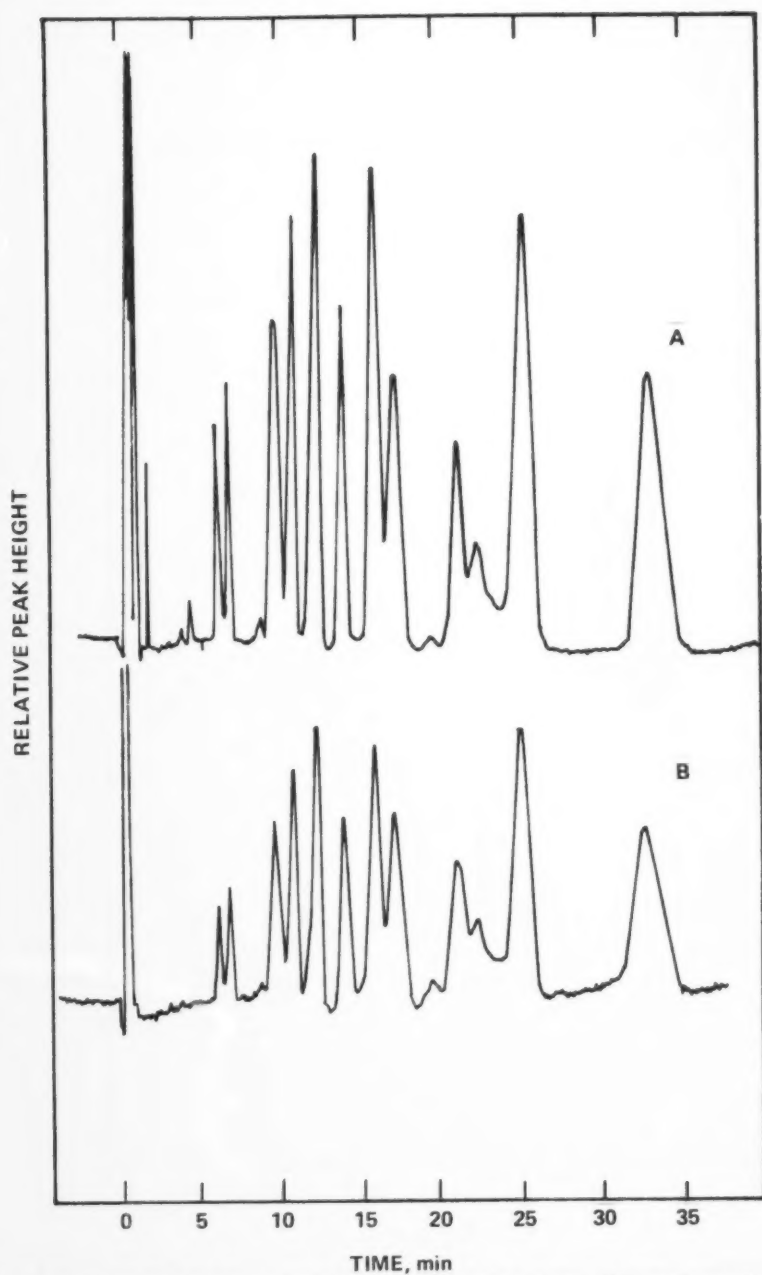


Figure 14. Location of the practice dig near Inez, N.C.



- A. EXTRACT FROM PCV FILTER WORN BY 2ND HYDROSEEDER DRIVER DURING PCB SPILL CLEANUP,
1.3 ml, 5 μ l INJECTION**
- B. EXTRACT FROM FOAM PLUGS WORN BY 2ND HYDROSEEDER DRIVER DURING PCB SPILL CLEANUP,
1.4 ml, 5 μ l INJECTION**
- C. AROCLOR 1260, 0.50 ng, 5 μ l INJECTION**

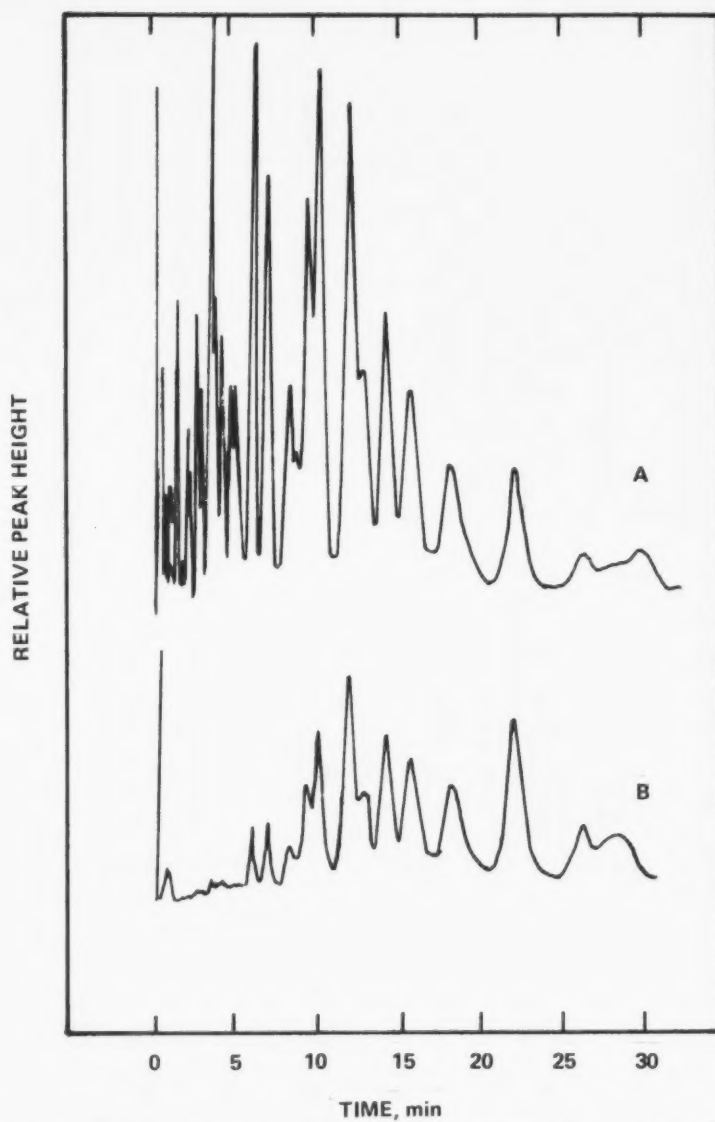
Figure 15. Chromatograms of personal monitoring sample extracts and Aroclor 1260 standard, SE-30/OV-210.



**A. SAMPLE EXTRACT OF ROADSIDE DIRT AND ROCKS FROM NC 87 IN CHATHAM COUNTY, 10g sample
in 1.08×10^5 ml, 5 μ l INJECTION**

B. AROCLOR 1260, 0.50 ng, 5 μ l INJECTION

Figure 16. Chromatograms of spill sample extract and Aroclor 1260 standard, OV-101.



A. EXTRACT OF SAMPLE COLLECTED OVER SPILL ON NC 210 ON 8/11/78, 12 ml, 5 µl INJECTION
B. AROCLOR 1260, 0.50 ng, 5 µl INJECTION

Figure 17. Chromatograms of Aroclor 1260 standard and ambient sample extract from highway PCB spill site, SE-30/OV-210.

Table 15
Aroclor 1260 Data from Roadside Spill Sites

Site	Date	Location	$\mu\text{g}/\text{m}^3$ Aroclor 1260
SR 1346	8/11/78	directly over spill	10.8
		6.1 m upwind	0.22
		12.2 m upwind	0.01
		7.6 m downwind	0.54
		15.2 m downwind	0.24
NC 210	8/12/78	directly over spill	4.8
		30 m downwind	0.04
		46 m downwind	0.01
NC 210	8/26/78	directly over spill	2.1
		7.6 m upwind ^a	0.28
		15.2 m upwind ^a	0.46
		7.6 m downwind	0.05
		15.2 m downwind	0.03
NC 210	9/9/78	directly over spill	0.39
		7.6 m upwind ^a	0.06
		15.2 m upwind ^a	0.17
		7.2 m downwind	0.07
		15.2 m downwind	0.05

^aThese upwind sites were located next to a driveway. There could be a secondary source of PCB emission further upwind causing these elevated levels.

Table 16
Profiles of Ambient Aroclor 1260 Concentration Over Spills

Date	Location	Distance above ground surface					Comments
		0.02 m	0.3 m	0.6 m	1.2 m	1.8 m	
8/16/78	Chatham Co. (US 421)	57	2.1	3.2	0.52	0.45	no charcoal
10/4/78	Warren Co. (NC 58)	0.9	0.09	0.02	0.01	<0.01	charcoal, before dig
10/12/78	Warren Co. (NC 58)	0.05		0.14		<0.01	after dig
11/7/78	Warren Co.	0.14	0.05	<0.01	0.05	0.03	after dig

All amounts are in $\mu\text{g}/\text{m}^3$

Table 17
Indoor Levels of Aroclor 1260 Near Highway Spill Sites

Date	Location*		$\mu\text{g}/\text{m}^3$
8/12/78	Johnston Co.	kitchen	0.19
		bathroom	0.04
		bedroom	0.08
8/26/78	Johnston Co.	kitchen	0.07
9/19/78	Warren Co.	Inez Country Store (3)	0.01
		Thorne house (4)	<0.01
		Thorne barn (5)	<0.01
		Thompson Grocery (1)	0.10
		Farm building (7)	0.01
		Thompson house (2)	0.02
10/4/78	Warren Co.	Fleming house (6)	0.10
10/5/78	Warren Co.	Inez Country Store (3)	0.01
		Fleming house (6)	<0.01
		Farm building (7)	<0.01
10/12/78	Warren Co.	Inez Country Store (3)	<0.01
		Fleming house (6)	<0.01
		Farm building (7)	<0.01

*The numbers refer to locations indicated on Figure 14.

Table 18
Airborne PCB Concentrations Near Test Removal Site
in Warren County, North Carolina^a

Site	Date	$\mu\text{g}/\text{m}^3$
A	10-4-78	--
	10-4-78	0.064
	10-12-78	0.010
B	10-4-78	--
	10-5-78	0.011
	10-12-78	0.013
C	10-4-78	0.022
	10-5-78	0.007
	10-12-78	0.008
D	10-4-78	0.014
	10-5-78	0.023
	10-12-78	0.006
Dumpsite 1	10-4-78	0.024
	10-5-78	0.034
	10-12-78	0.012
Dumpsite 2	10-4-78	0.011
	10-5-78	0.014
	10-12-78	0.007

^aData courtesy M. D. Jackson, Health Effects Research Laboratory, Research Triangle Park, North Carolina.

Table 19

Levels of Aroclor 1260 in Breathing Zones of Workers
During Test PCB Spill Removal

Position	$\mu\text{g}/\text{m}^3$
1st hydroseeder operator	<0.4
Motorgrader operator	<0.1
Athey Loader operator	<0.1
Dump truck drivers - 1	<0.4
- 2	<0.4
- 3	0.15
- 4	0.14
Dump truck coverer	0.10
2nd hydroseeder operator	0.57
Sweeper operator	0.82
Dumpsite worker	0.34
Supervisors - 1	<0.1
- 2	0.23

SECTION IX

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